AFHRL-TP-84-52

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TRENDS SHAPING ADVANCED AIRCREW TRAINING CAPABILITIES THROUGH THE 1990s

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March 1985
Final Technical Paper for Period July 1983 - July 1984

LABORATORY

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFHRL-TP-84-52	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Operations Training Division Air Force Human Resources Laboratory 6b. OFFICE SYMBOL (If applicable) AFHRL/OT	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code) Williams Air Force Base, Arizona 85240-6457	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Air Force Human Resources Laboratory 8b. OFFICE SYMBOL (If applicable) HQ AFHRL	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code) Brooks Air Force Base, Texas 78235-5000	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
62205F	1123	37	01

11. TITLE (Include Security Classification)
Trends Shaping Advanced Aircrew Training Capabilities Through the 1990s

12. PERSONAL AUTHOR(S)
Hughes, Ronald G. Brown, Larry

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM Jul 83 TO Jul 84	March 1985	20

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB. GR.
05	08	00
05	09	00

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
aircrew training; instructor operator station; computer image generation; onboard simulation; embedded training; ranges

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Simulation will become a major training system resource for the support of tactical aircrew training in the 1990s. Technologies in this area will be driven by the desire to extend the traditional notion of a "simulator" to that of a multi-cockpit multi-sensor device capability by the late 1980s. The ultimate user goal will be to arrive at those configurations of this new technology which prove to be cost effective for fielding at the base (wing and/or squadron) level.

Critical technologies for making such unit-level basing possible lie chiefly in the area of visual system display. In particular, unit-level basing of an advanced simulation capability will depend in large part on the success of head- and eye-coupled display technology and the anticipated reductions in overall system costs associated with adoption of such an approach.

Near-term training device research and development (R&D) goals call for the functional integration of a multiple-cockpit, multiple-sensor device capability (using head and eye coupling either in a helmet display or dome configuration) with a state-of-the-art, instrumented range facility by the early to mid-1990s. This centralized, "center" concept represents a significant R&D goal as well as an operational milestone with respect

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Including Area Code)	22c. OFFICE SYMBOL
Nancy A. Perrigo Chief, STINFO Office	(512) 536-3877	AFHRL/TSR

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

Block 18 (Continued):

simulators
training center
visual display

Block 20 (Continued):

to planning for future aircrew training systems, for it will create an important prototype or baseline for making important training effectiveness and training frequency decisions relevant to both an expansion of the center concept, as well as for an eventual, unit-level training capability.

In short, the 1990s will see not only the continued exploitation of new technologies for the improvement of simulator and range technologies, but also major attempts to integrate major resources into totally new training system concepts (e.g., the centralized training "center"). Significant new technology initiatives will also be undertaken, aimed at ensuring a vastly improved continuation training capability at the unit level. Common interservice needs to develop viable unit-level training will provide a firm R&D basis for the investigation of onboard simulation and embedded training system technologies.

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Paper presented at the 1984 Air Force and Navy Science and Engineering Symposium, Norfolk, Virginia, 14-16 November 1984.

SUMMARY

Simulation has the potential for becoming a major force multiplier influencing aircrew readiness in the 1990s, but not if given a continuation of the narrow focus characterizing the field today. Major underlying reasons are perceived to be more closely related to the lack of sound training "system" design, than to engineering or technology issues per se. Computer image generation and newer "hybrid" systems will prove capable of satisfying current and projected scene content requirements. Head- and eye-coupled display systems will both reduce overall visual system costs as well as provide high-brightness displays with resolution able to support even the most visually demanding tasks. Hardware costs will moderate but software costs will continue to increase, especially as increased capability leads to the requirement for the simulation of greater mission complexity. Together, these factors will work against the need to field this new technology at levels (e.g., wing and squadron) where frequent aircrew practice of critical skills can be assured. Instead, costs will continue to drive the user to centralized facilities for both advanced range and simulator systems alike. Access to training at this level will continue to be infrequent, on the order of every 12-18 months. Because of these trends, potential advantages are possible through a functional (and in some cases geographical) integration of major aircrew training resources, advanced simulators, and instrumented ranges. A substantially improved continuation training capability at the unit level will require improved concepts of onboard simulation and embedded training. These concepts, to the extent that they would make maximum use of the operational equipment itself, must be consistent with the need for training system capabilities adequate to support Air Force 2000 needs to field and sustain a highly mobile and dispersed force.

PREFACE

This paper was generated as a part of a program of research documented by the Air Force Human Resources Laboratory's (AFHRL) Technical Planning Objective No. 3, the main thrust of which is aircrew training. The general objective of this thrust is to identify and demonstrate cost-effect training strategies and training equipment capabilities for use in developing and maintaining the combat effectiveness of Air Force aircrew members. This paper was prepared for presentation at the 1984 US Navy - US Air Force Science and Engineering Symposium held at the Norfolk Naval Air Station, Norfolk, VA, 14-16 November 1984. Opinions expressed in this paper are those of the authors and do not necessarily represent an official position of the Laboratory or the United States Air Force.

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I. INTRODUCTION

The purpose of the present paper is to explore, in the most generic sense possible, what the "next generation" of advanced, aircrew training capabilities may be like. The results are based on certain assumptions concerning the continued development and use of simulation for military training and the application of related technologies to training settings which rival the performance environment of combat itself. The paper centers around flight simulators and training ranges, as currently conceived, with emphasis on those aspects which are important primarily for their perceived instructional/training value.

The primary emphasis of the present paper is on simulators, as opposed to ranges, and on the major trends that are perceived to shape future capabilities in this area. It is not the intent of this paper to provide a comprehensive review of simulator training features nor to comment on their current level of utilization. (See Bailey & Hughes, 1980; Bailey, Hughes, & Jones, 1980; Hughes, 1978, 1979; Hughes, Hannan, & Jones, 1979; Hughes, Lintern, Wightman, Brooks, & Singleton, 1982; Polzella, 1983; Ricard, Crosby, & Lambert, 1982; Semple, Cotton, & Sullivan, 1981.)

The paper is oriented toward the behavioral, as opposed to engineering, aspects of advanced simulation capabilities (Bailey & Hughes, 1980); the chief concern is with the functional aspects of training and instruction, and not with the manner in which such functional training capabilities are achieved. The paper is more speculative than prescriptive. The purpose is not to generate a list of simulator training feature "requirements." In fact, the discussion which follows is not, in the majority of instances, descriptive of particular individual "features" per se, but rather is "speculative," at best, about the broad class of capabilities likely to be found on such advanced training devices.

A primary motivation of the discussion is to make the point that one cannot adequately characterize the nature of such advanced training features/capabilities independently of the manner in which one conceives of the basic training system structure itself. Not only the technological state-of-the-art but also the ability to cost-effectively implement and field that technology will determine the structure of future training systems.

II. SPECULATIONS ABOUT FUTURE TRENDS

"Speculations" concerning the nature of "next-generation" training features/capabilities depend not only on the future state of the simulator-specific technologies per se (e.g., image generation, visual system display), but also on those technologies which support other major training resources as well (e.g., training ranges, ground-based and airborne computerized threat simulation, time-state-position instrumentation, onboard/embedded systems).

Assumptions, too, are dependent on the level of training for which simulators will be used in the future; that is to say, whether the predominant use will remain that of initial/basic skills acquisition or the primary application will be the integration and maintenance of those higher-order skills exercised under combat or combat-like conditions.

Interactions Between Expanded Technological Capability and Actual Training Capability

A direct relationship does not always exist between technology's ability to satisfy a particular training need and the user's ability to transfer that technology into an effective component of an overall training system. The following sections attempt to draw attention to this fact by pointing out certain relationships between cost, capability, and eventual training impact.

Simulators for Higher-Order Skill Integration and Maintenance

As major weapon systems increase in cost and complexity, there appears to be little doubt that simulation will continue to play an increasing role in military training systems, both at the level of initial skills acquisition and at the level of advanced skills integration and skills maintenance. At the present time, most simulators are used for basic skills acquisition. This is not to imply that the use of current devices is being misdirected toward "simple" skills, but rather that the strategies and approaches appropriate to this instructional level are more closely related to teaching methods associated with basic-skill-level instruction. The frequent use of simulators for initial-level training is more a function of the state of the current technologies in the areas of visual display than it is a matter of user intent. Despite the fact that research and development (R&D) devices, such as the Advanced Simulator for Pilot Training (ASPT) and the Simulator for Air-to-Air Combat (SAAC), have been used to show substantial gains in both offensive effectiveness and survivability (see Hughes, Brooks, Graham, Sheen, & Dickens, 1982; Jenkins, 1982), such device capabilities are not widespread within the operational community.

Future Impacts of Lower Component Costs and Increased Capability

Even though the future costs associated with critical simulator component technologies may decrease, the capabilities which advancements in these technologies will make possible will dramatically increase. Although a simulator with today's capabilities may cost less in the future, the increased capabilities afforded by technological advances will serve either to maintain or to increase procurement costs for military training devices. This trend will, in all likelihood, work against the desire on the part of the user to field the most advanced and most capable technologies at the operational unit level. If such is the case, the trend toward improved device capability will be misleading with respect to its impact on aircrew readiness, since infrequent aircrew access to such training will continue to be the chief behavioral obstacle to sustained performance improvement.

This trend toward increased capability in devices whose numbers will remain extremely limited will also have the effect of forcing a major centralization of such advanced training capabilities into training "centers." The trend toward increased centralization of limited training resources, if not pursued beyond that point, threatens to exert a force counter to requirements for increased mobility and increased dispersion of forces in the decades to come.

The training center, however, can serve an important function in an overall tactical training system when integrated with a viable unit-level training capability. Before the concept of a training center can be more closely examined, some discussion is needed regarding those technologies that are likely to exert the most significant impact on the use of simulators in the 90s.

The Changing Emphasis in Visual Image Generation and Display: Increased Emphasis on Visual Display as Opposed to Image Generation Capabilities

With regard to the simulator component technologies themselves, it is assumed that visual system limitations (e.g., limitations in the areas of scene content, field of view, resolution, brightness, contrast) and their associated costs will cease to be limiting factors. In particular, the image generation side of the overall visual system equation will cease to be the most significant player; instead, the means for displaying the imagery will become the major engineering challenge. There is ample evidence that this has already become the case.

With respect to image generation capabilities of future military training devices, it is assumed that the capability will exist to easily generate multiple image "types" (e.g., out-of-the-window, radar, electro-optical) from the same physical data base and that such a capability will be able to support the increasingly, sensor-based aspect of future military missions. Paralleling advances in the visual technology areas are assumed to be a greatly improved capability for interacting with elements of the visual data base, both for more rapid and flexible data base generation and for real-time manipulation of objects contained in the visual data base. The ability of the visual system to support recognized instructional principles of discrimination training will be critical to effective sensor training. Direct instructional control over the various visual elements contributing to task difficulty in the overall sensor-based mission will be of utmost importance.

With respect to the display of these image forms, it is assumed that head- and eye-coupled display technologies will be perfected to the point where requirements for large field-of-view displays will be satisfied using a minimum of image generation channels (Neves, 1984; Tong & Fisher, 1984; Welch & Shenker, 1984). With a reduction in the number of required image generation channels, the system costs for visual simulators may become manageable enough to permit operational basing concepts beyond the center level. With head and eye coupling will also come the instructional support capability of being able to monitor operator point of gaze and of being able to use such information in a response-contingent manner for instructional purposes.

In short, the assumption here is that head and eye coupling represents a critical technology, the applications of which, will become increasingly pervasive throughout the decade of the nineties, not only with respect to simulator display technology but also with respect to actual in-flight applications.

Augmented and Enhanced Cueing and Feedback

When one dares to depart from the design goal of the visual system as being that of attempting to duplicate visual "reality," then the medium becomes an extremely powerful instructional tool. It has been shown, for example, that the acquisition of difficult tasks can be facilitated through the use of visual cues not normally present "in the real world" (Hughes, Paulsen, Brooks, & Jones, 1978; Kaul, Collyer, and Lintern, 1980; Lintern, 1980). A reasonable assumption is that there will be an increase in attempts to merge the type of graphic analysis associated with post-mission debriefing displays (e.g., Information Management, Inc, 1983) with the primary purpose of out-of-cockpit and sensor displays. Integrated use of such an analytical, graphics-based capability along with, or in close conjunction with, the primary display medium, may substantially enhance the ability of the aircrew to develop situational awareness in complex

threat environments. It is anticipated that substantial emphasis will be placed on the use of augmented visual feedback (either for the instructor, the trainee, or both) for the display of information related to electronic combat engagements and effects. In this and other areas, augmented visual displays will make it possible for trainees and instructors alike to adapt more directly to what are otherwise invisible events in the real world (see Coblitz, Verstegen, & Hauch, 1983).

Workload Measurement

Consistent with the intent of integrated, mission-level training is the concern with workload. The assumption here is that as simulator component technology advances on the one hand, so will the independent understanding of workload (Frazier & Crombie, 1982). With increased understanding of workload will come the means for effective, unobtrusive methods for monitoring workload in a full-mission context. Where workload either is measured or is inferred from direct observation of operators' visual performance, the same technologies that will make possible head- and eye-coupled displays will also provide the means for monitoring this component or indicator of workload. With improvements in psychophysiological instrumentation methods, techniques, and telemetry, additional indications of workload will also become available (Reader, 1982). Together, various workload metrics (physiological, primary task performance, secondary task performance, etc.) may be used as joint criteria for syllabus proficiency advancement.

Embedded Simulation Models for Real-Time Performance Shadowing and Diagnosis

It is predicted that the next decade will witness a coming together of the traditional areas of mathematical simulation (modeling) and man-in-the-loop simulation. Mathematical models are already being used to generate weapon flyouts for both real-time kill removal determination as well as for generating post-mission debriefings to supplement feedback from range environments where natural feedback is lacking. In conjunction with this increased reliance on analytical reconstructions of mission performance shall be an increase in the use of such models for "shadowing" real-time performances both on the range and in the simulator. When combined with advanced data-processing capabilities, such shadowing promises to improve both real-time and post-mission diagnostic capabilities. Such diagnostic feedback, when combined with workload and performance metrics, might--again with the help of artificial intelligence--provide an effective adaptive training capability. It would be wise, however, not to expect too much, at least at first, with respect to the ability to effectively use artificial intelligence methods to transform inherently complex performance problems to simple, more manageable, components.

Centralization and Collocation of Major Training Resources (e.g., Training Ranges and Simulators)

The concept of a training "center" was mentioned previously with respect to the containment of major simulator resources within a limited number of geographically fixed "training centers." The center concept, and the centralization of training associated with a center concept, is generally viewed as necessary, due primarily to simulator affordability concerns rather than underlying instructional concerns.

As was pointed out previously, a major concern regarding "centers" is that the center alone will not be able to provide aircrews with frequent enough access to the center for performance gains to be effectively maintained over time. Although such an assumption begs for supporting

empirical data, it is inconceivable that rehearsal (practice) requirements for skills such as those underlying aircrew performances in combat should be any less rigorous than those for individual and team performances at the professional level of any sport (see Martin, 1984).

The training "center" concept is not, however, one that should be discarded because of its inherent frequency-of-training limitations. Such centers will prove valuable for the validation of tactics under combat-like conditions. Validated tactics, in and of themselves, will lead to improvements in aircrew effectiveness and survivability even for those aircrews who do not directly participate or who participate only infrequently in such tactics development exercises. Equally important, from a strictly pragmatic standpoint, is the fact that the center concept represents an affordable training system concept that can be implemented in the near term, even though the same technology may remain cost prohibitive for unit-level application.

Because the number of centers will be limited, it must be assumed either that individual trainee/operator access to such centers will be very infrequent or that the intent of the center will not be to provide training to the individual trainee/operator, but to provide such training only to some subset of operators. These operators (e.g., unit weapons/tactics officers) would, in turn, disseminate the effects of this training to unit-level personnel. If the training center is to be effective, it is essential that there exist an effective unit-level training capability to which to transfer "lessons learned" at the center.

The Integrated Simulator/Range Training Center

The training center concept, however, is more than simply a finite number of major, geographically fixed simulator facilities. Because the 1990s will be characterized not only by limitations on major simulator resources of this type, this time frame will also be characterized by continued limitations on adequate training range facilities. It has been proposed that the center concept be broadened to include the co-location and full functional integration of major simulator centers and instrumented range facilities. Examples of instrumented range capabilities include the Air Combat Maneuvering Instrumentation/Range (ACMI/R) and the Tactical Air Combat Training System (TACTS). The concept of an integrated simulator/range training center represents a potentially powerful training system concept for the following:

1. Providing a significant and measurable improvement in the effectiveness of range training (measured in terms of the quality of the aircrew end product) through the coordinated use of the flight simulator to raise the entry-level range skills of the aircrew.

2. Maximizing the complementary training/instructional aspects of flight simulator and range capabilities (i.e., use of the simulator for acquisition/maintenance of skills/techniques and use of the range for skill integration/composite force exercise training).

3. Providing an instrumented "test bed" for the development and evaluation of an operational mission planning and combat mission rehearsal capability.

4. Providing a real-time, interactive capability between simulator and range for the execution of selected aspects of composite force range exercises requiring a high degree of interaction between surface threat and aircraft (e.g., the Wild Weasel) and a lesser degree of interaction with main elements of the strike force.

5. Incorporating diagnostic mission rehearsal, debrief, and "refly" capabilities of the flight simulator with feedback and debrief capabilities of the instrumented range.

6. Providing an immediately accessible criterion for assessing and/or monitoring simulator training effectiveness.

7. Reducing the negative impact of temporal and geographical factors, as well as related costs, associated with providing frequent aircrew access to major simulator and range components of combat crew training.

8. Providing a significantly improved developmental test and evaluation environment for advanced weapon systems concepts.

9. Providing a critically needed tactics development and evaluation tool.

Advanced Training Features for the Integrated Simulator/Range Training Center

A host of possibilities is available for advanced training features associated with a multiple-cockpit, multi-sensor device capability. Although such multi-ship training is routinely conducted in the aircraft, not until now has the capability existed for conducting such training in the controlled environment of the simulator.

Stimulus Control Versus Response Topography

The center or center-like training environment will be very different from the training environment used to support initial/basic skills acquisition. Rather than the emphasis being on the topography (or form) of the response under stereotypical environmental conditions, the emphasis will be one of integrating established "part-task" or component performances into a full-mission status and bringing these higher-order performances either under very precise stimulus control or seeking to establish their generalizability across the widest range of potential tactical contingencies possible. Stimulus control, as opposed to response topography (i.e., form), will become the driving consideration in planning for instructional features at this level of training.

The Evolving Instructor Operator Station (IOS)

Where such simulator training has been conducted in singleship and limited, multi-ship settings, the implications are clear that a major rethinking of the instructor's role (and those features that support this role) will be required, as will be a rethinking of the manner in which such performances are monitored and controlled from a remote instructional station. With the advent of a nominal, multi-cockpit device capability come the questions of independent and coordinated (interactive) use of cockpits; use of computer-generated elements to supplement man-in-the-loop participants; in-cockpit or off-line replay/debrief; performance measurement for team as opposed to individual performance; effective displays for real-time monitoring of engagements consisting of multiple, interactive elements; etc.

With the evolution of such advanced capabilities, the instructor operator station (IOS) will potentially take on other novel, but related, functions. Using current intelligence information, an operator, using the IOS, may directly configure the simulator for training by inserting information on current target and threat conditions. The pilot, or trainee, by using the IOS in a different mode, may accomplish mission planning . . . perhaps even with the aid of an embedded diagnostic capability . . . from the IOS. The pilot's mission plan is used by the simulator as a

basis for selecting appropriate performance measurement algorithms for rehearsal of the planned mission in the simulator. As the mission is rehearsed in the simulator, the mission tape can be "edited" in real time, on-line, resulting in a modified tape ready for insertion in the aircraft avionics.

When such a simulation capability is fully integrated with an instrumented range facility, (such as ACMI/R or TACTS), a multitude of novel opportunities for instructional intervention emerge. The inherent limitations of range systems to adequately portray critical after-launch cues associated with ground threats can be compensated for by the visual capability of the simulator to recreate, using stored range data, selected range engagements for re-execution in the simulator. When simulator and range are used in a coordinated manner, neither need be required to support a level of training unsuited to its inherent fidelity limitations. Mission replay or refly capabilities incorporating the full range of cues available in the simulator should greatly improve debriefing capabilities as well. With additional processing of the stored performance data, the visual display capability of the simulator can be merged with that of the existing, graphic debriefing station to provide novel, and effective, in-cockpit perspectives.

Shared Feedback Components

With respect to feedback, it is assumed that these limited training centers will be co-located and functionally integrated with instrumented range or exercise facilities. The functional integration of range and simulation device suggests a multitude of possible instructional features. At a minimum, one would anticipate having common performance measurement modules capable of serving both range and simulator. Additionally a high degree of commonality would be expected between measurement algorithms used for range and those for the simulator; also the means by which range and simulator instructors oriented to such information (visually as well as in printed form) would have a high degree of commonality. The same assumption about commonality would apply also to the measurement and subsequent debrief of information gathered from onboard or embedded training systems.

When the simulator and range are thought of as an integrated instructional unit, other possibilities present themselves. Consider, for example, those exercise elements (on the range) having a requirement for a high degree of interaction with various aspects (e.g., threat) of the scenario but with a lesser requirement for interaction with the other elements of the range exercise. An Air Force example might be the F-4G (Wild Weasel); an Army example might be the use of artillery. Such exercise elements might, for example, be performed in a simulator and the effects generated in the simulator used to effect corresponding, real-time changes in range system target and threat status.

When the simulator is linked in real time to the range element, the possibility exists for a new level of instructor involvement in the range environment. Imagine the instructor seated either at the (IOS) or "flying" the simulator as a "phantom" element of the actual flight on the range. The instructor, using the large field of view of the simulator cockpit and the powerful capability to select any desired eyepoint, might even choose "to set himself in the backseat" of one of the single-seat fighters. The instructor might additionally choose, while viewing the fight from the pseudo-backseat position, to rotate positions so as to obtain an unobstructed view of the fight. From the backseat position and having perfect knowledge of all elements in the fight, the instructor would be in an ideal position to provide instructional prompts and other information to the pilot in the actual aircraft. Using the same capability for selecting any desired eyepoint, the instructor might move from plane to plane, or even choose to occupy the viewpoint of one of the opposing aircraft or ground threat site . . . and to do all this in real time. Such a capability would have the obvious advantage that the instructor would at all times

be totally invisible to the main players, but at the same time have all same involvement that an airborne instructor might have, plus the additional information and perspectives that only the flight simulator and its associated visual system could provide.

Performance Measurement Requirements

The type of tasks that will be rehearsed at the center level will result in an increased emphasis on performance measurement, especially as it relates to accuracy requirements for monitoring and scoring weapons effects. Performance measurement requirements are expected to become more prescriptive and more diagnostic, as opposed to simply descriptive. In the multiple-cockpit, composite-force exercise environment, performances will be characterized more at the level of the fighting element. Performances at this level, to be monitored effectively, will require a significant degree of on-line processing of individual and element-level performance data. Instructors will be more interested in the "flow of the battle" and less with individual performance metrics. New display concepts must be developed which are not limited by the current sequential nature of displays. Display formats must be developed that enable the instructor to process different information sources in parallel. Aiding in this level of instructor interaction with the battle will be the use of artificial intelligence driven, embedded system models.

Unit-Level Simulation Capabilities

While it would be ideal to think in terms of an eventual ability to "download" the center-level training capability to the level of the operational unit, the plan must consist of alternatives which are do-able in the near-term timeframe and which would serve to complement the training "center" concept now under consideration.

One option is to pursue the use at the unit level of "onboard simulation" approaches or embedded training system methods that rely on day-to-day use of the operational equipment itself (Lambert, 1982; Bailey, 1983; Breglia & Coblitz, 1984; Landy, 1980). Such a notion would be consistent with projected trends for increased dispersion and increased mobility of fighting forces in the future. This assumption could prove wrong should the cost of the technology become so affordable as to allow a significant downloading of training center-level capability to the unit level. If this should prove to be the case, the remarks to be made relative to center-level instructional features would also apply to instructional features found at the operational unit level.

Several of the aspects of onboard and/or embedded training system approaches serve to drive instructional considerations. In the case of current airborne systems, most rely upon a post-mission reconstruction of events for their implied effectiveness. Real-time feedback is often deficient or lacking. Careful consideration must be given the impacts of this lack of real-time feedback. There is a substantial literature to suggest that the mere post-performance replay of events is not a sufficient condition for performance change. "Training features" should not be considered as limited only to those things that an instructor might do in conjunction with an IOS or IOS-like device, but rather, that they encompass all those features which serve to ensure that learning takes place.

With regard to onboard simulation concepts such as those demonstrated with the Air Force F-15 Integrated Flight and Fire Control Onboard Simulation capability (Lambert, 1982; Landy, 1980),

limitations on the display of critical out-of-cockpit visual cues may well be overcome with the introduction of improved helmet display concepts in the operational cockpit. By capitalizing on improvements in image generator size and weight, it may be possible for operational equipment to have an internal computer image generation capability onboard (Breglia & Coblitz, 1984). Such a capability would prove valuable not only for extending the number of visually mediated tasks that could be trained in the system, but also for visual augmentation of actual mission cues (e.g., missile launch cues and signatures) as well. Current capability for supporting air combat maneuvering engagements could be further improved through the incorporation of an onboard adaptive maneuvering logic to drive the actions of a fully interactive, "smart" opponent.

III. RESULTS

By all indications it would appear that simulation will continue to be a significant component of tactical aircrew training well into the 1990s. The technology in this area will be driven by the desire to extend the traditional notion of a simulator to that of a multi-cockpit, multi-sensor device capability by the late 1980s. The ultimate user goal will be to arrive at configurations of this new technology which prove to be cost effective enough for fielding at the base (wing or squadron) level.

Critical technologies for making such unit-level basing possible lie in the area of visual system display. In particular, unit-level basing of an advanced simulation capability will depend in large part on the success of head- and eye-coupled display applications and the anticipated reductions in overall system costs associated with adoption of this approach.

Near-term training device R&D goals call, by the early to mid 1990s, for the functional integration of a multiple-cockpit, multiple-sensor device capability (using head and eye coupling either in a helmet display or dome configuration) with a state-of-the-art, instrumented range facility. This centralized, center concept represents a significant R&D, as well as operational, event or milestone with respect to planning for future aircrew training systems; it will create an important prototype or baseline for making important training effectiveness and training frequency decisions relevant to both an expansion of the center concept, as well as for an eventual, unit-level training capability.

Desires to develop the "perfect" device will continue to drive the pursuit of new technology. Although the cost of the technology per se may in fact decrease, the desire for increased capability will work against the ability of the user to support an effective, day-to-day continuation training capability (at least of the traditional simulator type) at the unit level. Options for a unit-level capability rely on either a cost-effective downloading of the more traditional, center-type technologies, or the adoption of an onboard simulation or embedded training system approach at the operational unit level. Again, the effective application of head- and eye-coupled display technologies underlies both the potentially cost-effective downloading of center-like capabilities to the unit level as well as advanced onboard simulation concepts relying on in-cockpit computer image generation of visual displays.

The functional integration and co-location of major aircrew training devices and instrumented range facilities will be important too for the opportunity to investigate novel training features. Of particular interest will be those features that support the complementary use of advanced range and simulation concepts. The development of accurate and reliable methods for obtaining time-state-position information at all levels of the airspace will continue to be an important technology underlying effective performance measurement in the operational range environment. Such performance measurement is critical both on the range and in the simulator for

the accurate reconstruction of complex performance. It will be through the application of advanced data processing methods, and potentially artificial intelligence, that new perspectives will emerge from the graphic reconstruction of performance data. Such graphic reconstructions will provide new perspectives on the performances, not only to the aircrew but to the analysts as well. A secondary product of this capability to apply sophisticated analytical techniques to the display of complex performances will be training devices which allow the aircrew to experiment with the multiple contingencies (the what-if's) of advanced tactical situations in relatively inexpensive, desktop situations.

Undoubtedly, a key training area to be emphasized with this emerging capability to exploit the complementary training functions of the range and simulator will be that of electronic combat. Not only will a novel capability to reconstruct performances graphically in this area be developed and refined, but the most effective ways of using such reconstructions for aircrew debriefings will also be investigated. Augmented visual feedback applications will be pursued for use as performance aids both for the aircrew and for the instructor. Many of these advanced display concepts will eventually find their way into cockpit display applications. Artificial intelligence, as a substantive capability develops in this area, will be expected to provide support in real-time processing of an increasing volume of performance data.

And lastly, the traditional IOS will undergo an evolutionary process. The IOS will perform the multiple tasks of simulator mission control, mission planning, mission rehearsal and plan revision, and mission debrief. The graphics display capability which lies at the heart of the IOS will become the means by which complex performances are planned, remotely monitored, and analyzed. In short, the IOS will become the primary man-machine interface with operator and onboard aircraft systems, operator and simulator, and operator and range.

IV. CONCLUSIONS

The next decade will see no lessening of the trend to seek high-technology solutions to tactical and strategic problems. In some instances, the pursuit of new technology will provide novel and more effective ways of doing old things. In some instances, the pursuit of new technology may make only more expensive new ways of doing the same old thing. While today's training tasks may be trained better and at lower costs in the future, the same technology that brings increased cost effectiveness also whets the appetite for increased training capability. The bottom-line effect is that, in the end, fewer training devices will be procured, but they will do more and will do so at levels of cost that either approximate or exceed current costs.

While the rule of "fewer things that do more" may be an acceptable goal for the procurement of weapon systems, it is not an acceptable goal for training devices if it means that the majority of pilots, in the present case, never benefit from the capability. As long as aircraft tasks remain dependent on the performance of the trained pilot, the relationship between practice and proficient performance will still apply; that is: Only those performance tasks which are practiced will improve; those tasks which are practiced most frequently will show the greatest improvement; only through frequent practice will performance levels achieved through training be sustained; only where training conditions approximate the conditions of the criterion (i.e., combat) will training generalize to the criterion setting.

Some of the options believed to be available to the Air Force through the next decade have been explored, based on technology availability and the need to construct aircrew training systems consistent with the elementary training principles outlined in the previous paragraph. The primary point made was that advanced training capabilities and features must be understood

within a total training system context. Secondarily, an attempt has been made to speculate about the nature of training features that might logically follow from certain assumptions concerning technology trends and the means by which that technology might be effectively implemented.

The primary warning expressed in the paper is that the pursuit of training device technology for its own sake, while approaching the limits of a "perfect device," is not a sufficient condition to ensure that subsequent attempts to implement the "gold-plated" device will be successful from either a cost or a training standpoint.

From a positive standpoint, the technologies necessary to support an effective, day-to-day continuation training program for advanced tactical aircraft are within sight and are being effectively worked by the appropriate organizations within the Air Force. Foresight, however, must be applied in channeling these efforts into training system applications that will come in direct contact with the performance of the pilot in the field. A training system will be effective only to the extent that its resources are structured in such a way that they bring about the desired levels of performance change and are able to effectively sustain that level of performance over time. The product (high, sustained levels of pilot and weapon system performance) must never become secondary to the process by which technology and user needs interact to create new training and training device capabilities.

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